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AIR FORCE

HUMAN RESOURCES

EXPERT ESTIMATE METHOD OF GENERATING MAINTENANCE AND MANPOWER DATA FOR PROPOSED AIR FORCE SYSTEMS: USERS GUIDE

By

Daniel W. Sauer
Systems Research Laboratories, Inc.
2800 Indian Ripple Road
Dayton, Ohio 45440

Robert N. Deem
William B. Askren
ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

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AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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This technical report has been reviewed and is approved for publication.

ROSS L. MORGAN, Technical Director
Advanced Systems Division

RONALD W. TERRY, Colonel, USAF
Commander

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The objective on this effort was to revise a prototype users guide for collecting expert estimates of maintenance, manpower, and training data for new or proposed Air Force systems. The revision of the users guide was based on three separate efforts: a review of recent expert estimate studies, an application of the expert estimate method using the prototype users guide, and an independent evaluation of the guide by experienced manpower professionals. A revised users guide was produced. It contains the procedures for using the expert estimate method to collect maintenance, manpower, and training data for new Air Force systems. It also contains examples of engineering description packages and questionnaires as well as cost data associated with the expert estimate method.

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Item 19 (Continued)

support equipment
task difficulty
training time
troubleshooting difficulty

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SUMMARY

Background

The impact of new systems on human resource requirements should be assessed as early as possible during weapon system acquisition. Recent studies have suggested that estimates of maintenance, manpower, and training requirements for Air Force systems can be made in the early design stages by technicians with maintenance experience on similar, operational systems.

Objective

The objective of this effort was to evaluate and revise a previously developed prototype users guide for collecting expert estimates of maintenance, manpower, and training data for new or proposed Air Force systems.

Approach

The revision of the prototype users guide was based on information from three separate efforts: a review of recent expert estimate studies, an application of the expert estimate method using the prototype users guide, and an independent evaluation of the guide by experienced manpower professionals.

Results

A revised users guide was produced. It contains information on the background of the expert estimate method and its capabilities, limitation, and applications. Specific areas covered include the development of the engineering description package and the questionnaire, procedures for selecting estimators and collecting the estimates, and data reduction and analysis methods.

PREFACE

This study was performed by Systems Research Laboratories, Inc. (SRL), 2800 Indian Ripple Road, Dayton, Ohio. Technical direction was provided by the Advanced Systems Division, Air Force Human Resources Laboratory (AFHRL), Wright-Patterson Air Force Base, Ohio.

The AFHRL support was provided under Project 1124, Human Resources in Aerospace System Development and Operations; Dr. Ross L. Morgan was the Project scientist and Mr. Robert N. Deem was the Work Unit scientist.

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The authors wish to acknowledge the many individuals who contributed to this effort. Appreciation is extended to Aerospace Defense Command (ADC) personnel in the 754th Radar Squadron at Port Austin AFS, Michigan; and to Air Force Communications Service (AFCS) personnel in the 1972nd Communications Squadron, Eglin AFB, Florida; the 2179th Communication and Installation Group, Patrick AFB, Florida; and the 2046th Communication and Installation Group, Wright-Patterson AFB, Ohio. Appreciation is also extended to Tactical Air Command (TAC) personnel in the 56th Combat Support Squadron at Avon Park Air Force Range, Florida, and to personnel in the 75th Tactical Control Flight and the 728th Tactical Control Squadron at Eglin AFB, Florida. Special appreciation is extended to Maj. C. McGeehee and Capt. R. Lessard of Headquarters TAC for their assistance in obtaining data on the AN/TPS-43(E) radar system and coordination of visits to TAC units. Special appreciation is also extended to CMSGT May, Headquarters ADC, and to Mr. Paul Goldberg, Headquarters AFCS, for their efforts in coordinating data collection visits to their respective command's units.

Special thanks are extended to the following individuals for their efforts in evaluating the prototype users guide: Captains S. Griffith, L. Medal, and C. Shipman, and SMSGT Gentry of the Air Force Maintenance and Supply Management Engineering Team at Wright-Patterson AFB, Ohio; and Mr. L. Jordan and Capt. W. Radcliffe of the Air Force ASD/ENEC Office at Wright-Patterson AFB, Ohio.

EXPERT ESTIMATE METHOD OF GENERATING MAINTENANCE AND MANPOWER DATA FOR PROPOSED AIR FORCE SYSTEMS: USERS GUIDE

INTRODUCTION

The Expert Estimate Method

There are several techniques and methods available for predicting the human resource requirements for new Air Force systems. Among these techniques are the historical comparison method, task-analytic method, sovereign factors, modeling techniques and expert estimate techniques (Haines & Gael, 1963). The first four methods require vast amounts of data, complex machine processing, or the construction of sophisticated models to produce the human resource estimates. The expert estimate approach requires relatively little in terms of external support and, therefore, represents a relatively low-cost method for producing human resource estimates. The data base for the expert estimate approach is made up of the years of systems experience accumulated by Air Force technicians. It is this data base that the expert estimate technique can rapidly query with small investments of resources.

The expert estimate technique consists of four basic steps. First, an engineering description package is compiled for the new or proposed equipment or system under study. This description is based on the engineering data and specifications available during the early phases of system design. Second, a questionnaire is designed to collect the specific human resource estimates desired. The third step is to collect the estimates. This includes the selection of the appropriate kinds and quantities of technicians to serve as expert estimators and the completion of the data collection visits. The fourth step is to reduce and analyze the data. These, then, are the basic steps involved in using the expert estimate method. Each of these steps will be discussed in more detail in later sections of this guide.

Capabilities/Limitations of the Expert Estimate Method

Recent research (Sauer & Askren, 1978; Sauer, Deem, & Askren, 1979; and Whalen & Askren, 1974) on the expert estimate method has been directed toward determining the accuracy, reliability, and generalizability of the method for different types of human resource data and different types of system technologies. The research has shown that the method can produce accurate and reliable estimates of

1. Maintenance Task Times

2. Maintenance Person-Hours

3. Crew Size

4. Skill Level

5. Career Field/Air Force Specialty Code (AFSC)

6. Task Difficulty

7. Training Times

The method has also been used to collect estimates of support equipment requirements and estimates of the relative frequency of various types of maintenance tasks which may be required for a new component or system. Technicians participating in the research efforts to date, however, have not been able to produce satisfactory estimates of these types of data.

Applications for the Expert Estimate Method

The expert estimate approach to predicting human resources for new systems does not depend on the availability of prototype or actual system equipment. Estimates can be made with only an engineering description of the proposed system. For this reason, the expert estimate approach is ideal for use in the early design stages of new systems before prototypes are constructed. The impact of the system design on the human resources can be assessed and, if necessary, the design can be modified. Since system changes in the early design stages can be effected more easily and are less costly than similar changes made later in the system development process, the expert estimate method can play a significant role in the process of optimizing system cost and system performance.

The expert estimate method could also be used to compare the human resource impacts of two or more alternative systems, designs, or engineering solutions. Another application could be in projecting personnel costs and personnel needs for new systems. It could also be used to assist career field planners and training planners. The method could be used as a means of supplementing the data bases used for more sophisticated human resource estimation techniques or estimation models. Further research is expected to refine and expand the capabilities of the method as well as to define more clearly its most advantageous applications and limitations.

The following sections of the guide describe in detail the steps necessary to apply the expert estimate method. Where necessary, examples are provided to supplement the explanations of the steps.

DEVELOPING THE ENGINEERING DESCRIPTION PACKAGE

The first step in preparing to use the expert estimate method is to develop the engineering description package. This package will be the only source of information on the proposed system or equipment that the technician will have. As such, it is critical that as much pertinent information as possible be presented in the package. Generally, the engineering description package should contain the following types of information:

1. Type of System--Identify the type of system for which estimates are to be made, for example, a strategic bomber system, a cruise missile system, a hydraulic system, a mobile ground radar system, or an electronic countermeasures system.

2. Location of Components Within the System--Indicate where individual components are physically located within the system. Also indicate the spatial/physical relationships among system components and between system components and other systems.

3. Access to Components--Indicate, through detailed text or graphics, the extent to which other components, panels, or hatches must be removed to gain access to the system components.

4. Physical Description of Components--Size and Weight--Indicate component exterior dimensions, weight, shape, and any unusual mounting or attachment hardware associated with the component.

5. Functional Description of Components--Describe what each component does, its input data and its output data. Schematic or block diagrams are often helpful to describe the functional relationship among components.

6. Description of Built-In Test Capability--Describe what can be tested, when in the operation of the system the tests can be made, and how and in what form test results are presented.

7. Description of Test Equipment--Describe the types of test equipment other than built-in test equipment that are required for the system. Include generic names of test equipment and brand names if appropriate. Identify any special adapters, special power requirements, environmental conditions, or other special support equipment or facilities.

8. Maintainability--Include in the engineering description package any preliminary estimates of repair or maintenance times available during the early design stages.

These kinds of system information may be obtained from system designers and engineers through letters, interviews, briefings, conferences, or any other means available to transfer the engineering information to the user of the expert estimate method.

It is possible that many of the details will not be known or will not have been decided during the early design stages; therefore, the engineering description package should be developed from the data that are available.

There is no set format for the engineering description package. Experience has shown that schematics, block diagrams, flow diagrams, drawings, and other graphic aids were very helpful to the technicians who have used the packages. The length of the engineering packages used in the expert estimate research ranged from 10 to 15 pages of text and diagrams. Most of the technicians felt that these lengths were about right and some stated that they could have been longer. After the description package has been compiled, it is advisable to have a small group (5 to 10) of potential technician estimators review the package to ensure that all technical and engineering terms are clearly defined and understood.

The main cost of developing an engineering package will be the time necessary to collect, edit, and compile the engineering data in a single document. This includes the person-hours spent by the individual charged with preparing the engineering description package; the engineers or designers who will furnish the engineering data on the proposed system; drafting and artistic support; and typing, editing, and reproduction support. Travel expenses should also be considered if the data collector needs to visit distant locations to obtain required data.

DEVELOPING THE QUESTIONNAIRE

The development of the questionnaire is a process of selecting the appropriate question formats for the types of human resource estimates desired. Before discussing the specific question formats, it is necessary to address the construction of maintenance scenarios. The maintenance scenario serves as the frame of reference for the task time, crew size, skill level, task difficulty estimates, and derived person-hour estimates. The scenario presents information similar to what the maintenance technicians encounter in their daily AFM 66-1 recordkeeping activities. A maintenance scenario contains at least four types of information: (a) the identification of the component or subsystem (e.g., Work Unit Code), (b) identification of maintenance type (on- or off-equipment), (c) identification of the specific malfunction (e.g., How Malfunction Code), and (d) identification of the specific maintenance action taken (e.g., Action Taken Code). The Work Unit Code manuals for similar operational systems may be consulted to determine the types of malfunctions and maintenance actions which may be included for the proposed system. Maintenance scenarios may be specified for as many system components, maintenance types, malfunctions, or maintenance actions as necessary for the particular application of the expert estimate method. If, for example, a system was composed of 10 components and information was desired for five on-equipment and five off-equipment malfunctions and maintenance actions, it would be necessary to specify 100 maintenance scenarios (10 components × 5 malfunctions and/or maintenance actions × 2 maintenance types).

Maintenance Task Time Estimates

Maintenance task time estimates should be made for each maintenance scenario constructed. To help technicians estimate the normal task time for a given maintenance action, have technicians consider the full range of possible task times. The technicians should consider three task times: (a) the minimum time in which the task could be completed, (b) the normal time in which the task would be completed, and (c) the maximum time for task completion. The following is an example of a format which has been used successfully in previous research efforts. The four parts of the maintenance scenario are presented prior to the actual task time format.

Maintenance Scenario

Component: Transmitter (WUC-ABAOO)
Type Maintenance: On-Equipment
How Malfunction Code: No Output
Action Taken Code: Troubleshoot

Minimum Time	Normal Time	Maximum Time
1.2 (hours & tenths of hours)	1.8 (hours & tenths of hours)	2.5 (hours & tenths of hours)

Crew Size Estimates

Crew size estimates can be made in terms of the percentage of times a particular task will require a crew of one, two, three, or more members. Present the possible crew sizes for a particular maintenance scenario and have the technicians indicate next to each crew size the percentage of times that size crew would be required to perform the maintenance task. The following is an example of a format (with typical estimates) for collecting crew size estimates.

Maintenance Scenario

Component: Transmitter (WUC-ABAOO)
Type Maintenance: On-Equipment
How Malfunction Code: No Output
Action Taken Code: Troubleshoot

Crew Size	Percent of Time
1	85
2	10
3	5
4	0

The estimator predicts that 85 percent of the time that this task occurs, one person can perform the task; 10 percent of the time the task occurs, two persons are needed to perform the task; and 5 percent of the time the task occurs, three persons are needed to perform the task. The task will never require a crew of four persons according to the estimates presented here.

Person-Hour Values

In the expert estimate method, technicians do not estimate person-hours directly. When recording daily maintenance activities, technicians enter task time and crew size on the AFTO form 349 (Maintenance Data Collection Records). They are not required to think in terms of person-hours nor are data entered in terms of person-hours. For the expert estimate method, person-hour values are derived from the task time estimates and the crew size estimates. Specifically, each technician's estimates of normal task time and of the crew size most likely to perform the task are used to calculate person-hour values. For example, if a technician estimates that the normal task time for a given task is 1.9 hours and that 75 percent of the time a two-member crew is required, the person-hour value resulting from these estimates is 3.8 person-hours (1.9 hours × 2 crewmembers). A group mean person-hour value is calculated by finding the mean of the individual person-hour values. Person-hour calculations are accomplished during the data reduction and analysis phase for each maintenance scenario specified.

Skill Level Estimates

Skill level estimates should be made in conjunction with crew size estimates for a given maintenance scenario. Have technicians estimate the skill levels (3, 5, 7, or 9) for the member(s) of the crew(s) they estimated would be required to perform the task. The following formats (with typical estimates) illustrate how the skill level estimates may be made to correspond to the crew size estimates.

Maintenance Scenario

Component: Transmitter (WUC-ABA00)
Type Maintenance: On-Equipment
How Malfunction Code: No Output
Action Taken Code: Troubleshoot

Crew Size	Percent of Time	Skill Levels			
1	85	5			
2	10	5	7		
3	5	5	7	3	
4	0	__	__	__	__

In the example, the estimator indicates that when one person can perform the task, the 5-skill level is necessary. When two persons perform the task, one should have a 5-skill level, while the other

should have a 7-skill level. When three people perform the task, skill levels 5, 7, and 3 are required. Since four people are not required to perform the task, no skill level estimates are necessary.

Task Difficulty Estimates

Task difficulty estimates can be made for each maintenance scenario. Technicians rate the difficulty of the maintenance action taken for the proposed equipment on a task difficulty scale 100 mm long. Verbal anchors of "Very Easy" (0 mm), "Average Difficulty" (50 mm), and "Very Difficult" (100 mm) are added. Technicians should be advised to consider their past maintenance experience on similar equipment as a basis for rating the difficulty of the maintenance tasks for the proposed equipment. An example of a task difficulty scale is as follows.

Maintenance Scenario

Component: Transmitter (WUC-ABA00)
Type Maintenance: On-Equipment
How Malfunction Code: No Output
Action Taken Code: Troubleshoot

Very Easy	Average Difficulty	Very Difficult

Career Field/AFSC Estimates

Career field/AFSC estimates need only be made once, since they do not vary by maintenance action. It is recommended that these estimates be made after the technicians have completed the estimates for the various maintenance scenarios. It is helpful to identify for the estimators the group of current AFSCs from which technicians would most likely be chosen to maintain the new system. This information can be found in the Airman Classification Regulation, AFR 39-1. A series of questions is recommended to extract as much information from the estimators as possible. The questions should progress from an identification of the appropriate career field (the first three digits of an AFSC) to identification of a specific AFSC. Ask those technicians who cannot identify an appropriate career field or AFSC for the new system what steps would be required to obtain the necessary skills. The following is an example of a series of career field/AFSC questions.

Career Field/AFSC Estimates

In your opinion, could maintenance on this radar system be performed by personnel from existing Air Force career fields? Yes ___ No ___

If you answered yes, which career field do you think would be most likely to perform this maintenance?

____

Is there an AFSC in existence now which would be most likely to perform the maintenance on this radar system? Yes ___ No ___

If you answered yes, please identify the AFSC _ _ _ X _.
(AFSC)

If you answered no, which of the following actions do you think would be necessary to obtain the skills for this system?

_____ Create a new AFSC
_____ Combine existing AFSCs
_____ Create a new shredout for an existing AFSC

Training Time Estimates

Training time estimates can be collected for three types of training: (a) technical training, (b) field training detachment (FTD) training, and (c) on-the-job training. The estimates should be made in terms of the number of weeks required for each type of training. Research (Sauer & Askren, 1978) has shown that attempts to have technicians provide very detailed training time (in hours) and training syllabus content estimates during the early stages of design were not productive. Training time estimates may be made for two types of individuals: an experienced technician transitioning from a similar technology to the new system or a new airman, a basic training graduate ready to enter technical training in the technology associated with the proposed system. The following is an example of the format used to collect training time estimates.

Training Time Estimates

Assume that maintenance personnel for this system will come from both experienced radar maintenance technicians and Air Force basic training graduates. Further, assume that the experienced technicians have maintained the AN/TPS-44, a two-dimensional, nontracking, mobile, ground-based radar. The AN/TPS-44 consists of an antenna assembly, a van housing the transmitter, and a second van housing the PPI display. Estimate the training time in weeks required to accomplish the following types of training for both experienced technicians and basic training graduates.

	Number of Weeks of Training Required for:	
	Experienced Technicians	Basic Training Graduates
Technical Training	______	______
Field Training Detachment Training	______	______
On-the-Job Training	______	______

Notes on the Questionnaire

It is recommended that verbal directions be used to supplement the written instructions. It is strongly recommended that sample questions be included with the instructions to demonstrate how the formats are to be used. Technicians may never have encountered some of these formats and an example may be the most effective means to resolve any confusion.

COLLECTING EXPERT ESTIMATES

The major activities involved in collecting expert estimates are selecting expert estimators and conducting the actual field data collection visits. The procedures and recommendations for these phases of the method are presented below.

Select Expert Estimators

Expert estimators should be selected primarily on the basis of their systems experience. Research has shown that it is desirable to select as estimators the maintenance technicians with experience on equipment or systems similar to the proposed equipment or system. Satisfactory estimates have been obtained using technician estimators from the career field (first three digits of the AFSC) appearing to be most closely associated with the proposed system. If it is possible to identify the AFSC (all five digits of AFSC) that appears to be most qualified to maintain the proposed system, use estimators from that AFSC. Because of the variety of new systems under development, it is impossible to give any more specific advice on the ideal equipment or systems experience necessary.

Air Force Regulation 39-1, Airman Classification Regulation, and the Air Force Manpower and Personnel Center, Randolph AFB, Texas, are good initial sources for locating technicians who could participate as estimators and for identifying the Commands to which these technicians are assigned. Personnel specialists at the various Command headquarters can provide further assistance in locating the appropriate technicians within their Command.

Once the initial group of potential estimators has been identified, it is possible to select specific raters. In terms of skill level, it is recommended that at least 5-level personnel be selected as estimators. Research on expert estimators has not included sufficient numbers of 3-level personnel to assess the quality of their estimates. Research has also shown that the amount of system experience is not related to accuracy of estimates, provided the estimators are at least at 5-skill level.

The minimum recommended number of expert estimators is 25. Previous analyses (Sauer & Askren, 1978) of estimates from groups of 5, 10, 20, and 25 indicate that the variability in estimates decreases as the groups increase in size. There is less chance, therefore, of obtaining extremely high or low estimates with the larger groups. The person-hour cost data from recent research (Sauer, Deem, & Askren, 1980) show only a relatively small additional cost when increasing the number of estimators from 10 to 25.

Data Collection Visits

After the appropriate technicians have been selected and located, it is necessary to prepare for the data collection visits. A certain amount of lead time is necessary to schedule these visits. At least 6 weeks advance scheduling is recommended. A number of variables affect the actual amount of lead time necessary for a given situation. Some of the variables are security clearance procedures, command visit request procedures, type of personnel (military, civil service, or contractor) making the visits, and operations or deployment schedules of the units or squadrons to be visited.

Once the visits have been arranged, attention can be turned to the actual data collection procedures. The data may be collected in group sessions ranging from 2 to 15 technicians per session. The length of each session will, of course, vary with the number of estimates to be made. If a large number of estimates are to be made, multiple data collection sessions should be scheduled. In this situation, the same estimators may participate in multiple sessions. An alternative would be to divide the estimates into separate blocks, with each block assigned to a different but equally qualified group of estimators. In this approach, the estimators would only be required for a single session.

Experience with the expert estimate method has shown that, for planning purposes, one should expect five technicians per session and each data collection session would require approximately 4 hours of the data collector's time. These planning data allow for variations in the unit's work schedule. Depending on the work schedule, it may also be necessary to schedule sessions during second or third shift operations to obtain the required number of estimators.

The data collection session usually begins with a short briefing on the purpose of the data collection. This often increases the motivation of technicians to complete the questionnaires as carefully and accurately as possible. Verbal instructions should supplement the written instructions for the questionnaire. Technicians should be encouraged to first skim the engineering description package and then refer to it as often as necessary during the session. Point out that although the questionnaire is not a test, individual answers, rather than a group consensus, produce the best estimated data. Experience thus far in the research has shown that technicians require approximately 1 minute per page for initial reading of the engineering description and about 1 minute per estimate. Technician estimators in the research efforts to date have spent from 1.5 to 2.5 hours completing the questionnaires.

DATA REDUCTION AND ANALYSIS

The scope of the expert estimate method research effort has not been large enough to require data processing support for data reduction and analysis. Data reduction has only involved transferring data from the questionnaires to a consolidated data form. These forms simply provide a convenient method to handle the estimated data.

The analysis of the estimated data is fairly straightforward. The analysis procedures differ, however, for the various types of estimates. The product of the analysis is an estimate of a human resource data item. In some cases, this estimate is calculated directly from the data. In other cases, a correction factor has been applied to the basic data to arrive at an estimate. The following paragraphs will describe the analysis procedures for the maintenance, manpower, and training data and will note any correction factors which may be applied to the data.

Maintenance Task Time Estimates

Maintenance task time estimates for a new system are determined by finding the mean of the normal task time estimates made by the estimator group. If five technicians produce normal task time estimates of 1.4, 1.7, 2.0, 1.9, and 2.1 hours, the mean task time estimate for the group would be 1.82 hours [(1.4 + 1.7 + 2.0 + 1.9 + 2.1)/5]. The minimum and maximum time estimates serve only to help the estimator make the normal time estimate. Calculation schemes using all three task time estimates were tried in the analysis phase of previous studies (Sauer & Askren, 1978; Sauer, Deem, & Askren, 1980). None resulted in more accurate task time estimates.

A correction factor may be applied to the maintenance task time estimates. Based on previous research (Whalen & Askren, 1974), technicians tend to underestimate maintenance task time by approximately 71 percent. To arrive at a corrected group estimate of maintenance task time, divide the group estimate by .71. If the group mean task time estimate were 1.9 hours, the corrected group mean task time estimate would be 2.7 hours.

Crew Size Estimates

Analysis of the crew size estimates can result in group mean estimates of the percentage of times various crew sizes would be required for the task or a group estimate of the single most likely crew size required for the task. For either estimate, calculate the group mean percentage for each crew size. These percentages will indicate how often the task will be performed by one, two, three, four, or more crewmembers. The crew size most likely to perform the

task is the crew size with the largest mean percentage. For a given maintenance task, five technicians estimated the crew sizes as follows:

Crew Size	Technician A	Technician B	Technician C	Technician D	Technician E	Group Mean
1	30%	15%	40%	50%	10%	29%
2	70%	75%	60%	50%	90%	69%
3	0%	5%	0%	0%	0%	1%
4	0%	5%	0%	0%	0%	1%

In this case, a crew size of one would be required 29 percent of the times the task is performed and a crew size of two would be required 69 percent of the times. Crews of three or four would be required only 1 percent of the time the task was performed. The crew size most likely to perform this task is two.

The research has focused primarily on crew sizes of one and two. Until additional data can be obtained for crew sizes of three and four, it is not possible to recommend any correction factors for crew size estimates.

Person-Hour Values

Individual person-hour values are calculated by multiplying an individual technician's estimate of the most likely crew size (indicated by the largest percentage) by the individual's estimate of normal task time. A group mean person-hour value is then calculated from the individual person-hour values. If a technician estimates that a given task can be accomplished in 2.1 hours (normal task time) and that a crew size of two is most likely to perform the task, the person-hour value is found by multiplying 2.1 (normal task time) by 2 (most likely crew size) which yields 4.2 person-hours. If person-hour values calculated for the four remaining technicians in the group were 3.9, 3.8, 4.7, and 4.0, the group mean would be 4.12 person-hours [(4.2 + 3.9 + 3.8 + 4.7 + 4.0)/5].

The research has shown that person-hour values ranged from 66 percent to 74 percent of the AFM 66-1 person-hours used to validate the estimates. In other words, when the group person-hour values for specific on-equipment maintenance tasks were compared with the reported AFM 66-1 person-hour data for these same tasks, the group person-hour values were less than the actual person-hours. To bring the group person-hour values closer to the actual person-hours, a correction factor may be applied to the group value. Until additional data are available, the correction factor for person-hour estimates is .70. This value is midway between the values derived

from the Sauer and Askren (1978) study (.66) and the Sauer, Deem, and Askren (1980) study (.74) and is very close to the value for task times (not person-hours) derived from the Whalen and Askren (1974) study (.71). To arrive at a corrected person-hour value, divide the group person-hour value by the correction factor of .70. This yields corrected person-hours. For example, if the group person-hour value for a given task was 1.76, the corrected person-hours would be found by dividing 1.76 by .70. The corrected person-hours would be 2.51.

Skill Level Estimates

The analysis of skill level estimates is fairly straightforward for crew sizes of one and two. Those skill levels reported most often by the majority of estimators would represent the predicted skill level under the particular maintenance scenario. Although skill level estimate data for crew sizes of three and four are limited, it seems reasonable to obtain skill level estimates for these crew sizes in the same manner. For example, suppose five technicians estimated skill levels for a given task as follows:

Skill Level Estimates

Crew Size	Technician A	Technician B	Technician C	Technician D	Technician E
1	5	5	5	5	7
2	5, 7	5, 7	5, 3	5, 5	5, 7
3	3, 5, 7	3, 5, 7	5, 5, 3	5, 5, 7	3, 5, 7
4	-	-	5, 5, 3, 3	-	-

The estimated skill level for a crew size of one would be 5 (4/5, or 80 percent, of the responses) and for a crew size of two, the estimated skill levels would be a 5 and a 7 (3/5, or 60 percent, of the responses). For a crew size of three, the estimated skill levels would be 3, 5, and 7 (3/5, or 60 percent, of the responses). Although it is doubtful that a crew of four would be required for the task, the skill levels estimated for this size would be two 5-level and two 3-level technicians. No correction factors are involved with skill level estimates.

Task Difficulty Estimates

Task difficulty estimates are calculated by converting the marks on the 100-mm difficulty scale to scores. If five technicians estimated task difficulty as 75, 72, 55, 48, and 64, the group mean

task difficulty estimate could be 62.8, indicating that the task is somewhat more difficult than average tasks. After calculating the group mean task difficulty score for a particular task, a correction should be applied. Previous research has shown that technicians tend to underestimate the degree of difficulty of maintenance tasks on the proposed system by from 74 percent (Sauer & Askren, 1978) to 88 percent (Sauer, Deem, & Askren, 1980). That is, technicians rated the maintenance tasks on the proposed system as being less difficult than the criteria task difficulty ratings for the same tasks. To obtain a corrected task difficulty estimate, the mean task difficulty estimate must be divided by a correction factor of .81, a value midway between the percentages reported in the above studies. For a task difficulty estimate of 54, the corrected task difficulty estimate would be found by dividing 54 by .81, which would result in a corrected estimate of 66.7.

Career Field AFSC Estimates

The career field and AFSC estimates for a new system are simply the career field and AFSC identified by the majority of the technicians as appropriate for the proposed system. If a career field or AFSC is not clearly identified by the technicians, the other responses to the career field and AFSC questions should indicate whether a new career field (first three digits of AFSC) or new specialty (all five digits of AFSC) should be created or whether other modifications to existing AFSCs may be necessary. No correction factors are appropriate for career field/AFSC estimates.

Training Time Estimates

The first step in determining training time estimates is to calculate the group mean of the individual training time estimates. The mean training time estimates may be collected for three types of training: (a) technical training, (b) field training detachment training, and (c) on-the-job training; and two types of technicians: (a) the experienced maintenance technician transitioning to the new system, and (b) the basic training graduate ready to begin technical training for the new system. Suppose 10 technicians estimate the number of weeks of technical training required for a basic training graduate. Their estimates of 10, 6, 8, 10, 14, 16, 12, 11, 10, and 8 weeks result in a mean estimate of 10.5 weeks for a basic training graduate. Other training time estimates are calculated in a similar manner.

Correction factors (Sauer, Deem, & Askren, 1980) may be applied to all these estimates. The correction factor for training time estimates is handled in the same way as correction factors for maintenance task times and person-hours. The estimated training

times are divided by the accuracy scores to yield a corrected training time estimate. Table 1 contains the accuracy scores or correction factors for each of the three types of training and two types of technicians.

TABLE 1. TRAINING TIME ESTIMATE CORRECTION FACTORS FOR THREE TYPES OF TRAINING AND TWO TYPES OF TECHNICIANS

Types of Technicians	Types of Training Technical	 Field Training Detachment	 On-the-Job
Experienced Technician	.63	1.41	.89
Basic Training Graduate	1.13	2.74	.83

For example, if the group of technicians estimated that, for an experienced technician, 10 weeks of on-the-job training would be required, the correction factor would be .89. The corrected training time estimate would be 10 divided by .89 or 11.24 weeks of on-the-job training.

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GLOSSARY

AFTO Form 349--The title of this form is the "Maintenance Data Collection Record." It is used to record maintenance actions on various types of equipment. The data which may be recorded include: job identification data, component identification data, maintenance task time, crew size, type of maintenance, malfunctions, discrepancies, and specific maintenance actions taken.

Air Force Regulation 39-1--The Airman Classification Regulation defines and describes all Air Force occupational specialties and career fields and their training and skill requirements.

Air Force Manual 66-1--This manual, "Maintenance management policy," establishes the maintenance management system applicable to all Air Force activities engaged in the maintenance of aircraft, missiles, munitions, aerospace ground equipment, avionics, training equipment, and communications-electronics-meteorological equipment.

Air Force Specialty Code--The Air Force Specialty Code (AFSC) is a five-digit number assigned to Air Force enlisted personnel which defines the general career field and the specialty within the career field in which the individual is qualified and the skill level the individual has attained.

Career Field--Career Field represents a general area of expertise or technology in which an individual is qualified. The first three digits of the Air Force Specialty Code (AFSC) specify the individual's career field. For example, the career field of avionic weapon delivery systems (general area) will include three specialty areas: bomb-navigation system, defensive fire control systems, and weapon control systems.

Field Training Detachment Training--Field Training Detachments provide job-oriented maintenance training on assigned weapon systems, support systems, and selective equipment. The FTDs require host support in order to provide responsive and quality training.

Off-Equipment Maintenance--Maintenance activities which cannot be accomplished on the system. Maintenance must be accomplished in the maintenance shop.

On-Equipment Maintenance--Maintenance actions which may be performed on the system. No shop maintenance is required.

On-The-Job Training--Training which is accomplished in the course of normal operations or maintenance activities. The trainee learns by observing and/or actually performing real operations or maintenance tasks.

Skill Level--Skill level represents the level of qualification and degree of expertise achieved within the technician's career field and specialty code. The five skill level codes are 1, 3, 5, 7, and 9, with skill level 1 equivalent to a helper, skill level 3 equivalent to an apprentice, skill level 5 equivalent to a specialist, skill level 7 equivalent to a technician, and skill level 9 equivalent to a superintendent. This code appears as the fourth digit of an individual's Air Force Specialty Code (AFSC).

Technical Training--Formal classroom training conducted away from the job site at designated Technical Training Centers.

Work Unit Code--The work unit code is a five-character code used to identify systems, subsystems, and components for which maintenance is required or on which maintenance was accomplished.